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Rieger et al.

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[54] **LOW COST, HIGH AVERAGE POWER, HIGH BRIGHTNESS SOLID STATE LASER**

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[*] Notice: The portion of the term of this patent subsequent to Jul. 18, 2012, has been disclaimed.

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 295,283, Aug. 24, 1994, Pat. No. 5,434,875.

[51] **Int. Cl.**[6] **H01S 3/10**

[52] **U.S. Cl.** **372/25**; 372/5; 372/10; 372/12; 372/18; 372/22; 372/69; 372/92

[58] **Field of Search** 372/10, 12, 18, 372/5, 25, 69, 22, 92

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[57] **ABSTRACT**

A high average power, high brightness solid state laser system. We first produce seed laser beam with a short pulse duration and frequency in excess of 1,000 pulses per second. A laser amplifier amplifies the seed pulse beam to produce an amplified pulse laser beam which is focused to produce pulses with brightness levels in excess of 10^{11} Watts/cm^2. Preferred embodiments produce an amplified pulse laser beam having an average power in the range of 1 kW, an average pulse frequency of 12,000 pulses per second with pulses having brightness levels in excess of 10^{14} Watts/cm^2 at a 20 μm diameter spot which is steered rapidly to simulate a larger spot size. These beams are useful in producing X-ray sources for lithography.

In one preferred embodiment, the seed beam is produced in a mode locked Nd:YAG oscillator pumped by a diode array with the frequency of the pulses being reduced by an electro-optic modulator. In a second preferred embodiment, the seed beam is Q switched and includes a Pockels cell for cavity dumping. In a third preferred embodiment, the short duration high frequency pulses for the seed beam is produced by a very short Nd:YAG crystal and a λ/2 Pockels cell.

As compared with prior art high brightness lasers, we have achieved our very high brightness by reducing the pulse duration by about 2 or 3 orders of magnitude, from a few ns to 100 ps or less and by focusing on a very small spot, but we are able to simulate a much larger spot by very rapidly steering our high average power beam over the area we need.

30 Claims, 6 Drawing Sheets